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Nakatsuka et al.

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(54) **PICKLING DEVICE AND PICKLING PAUSE OPERATION METHOD**

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C23G 1/08 (2006.01)

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CPC C23G 3/021; C23G 3/025; C23G 1/08
(Continued)

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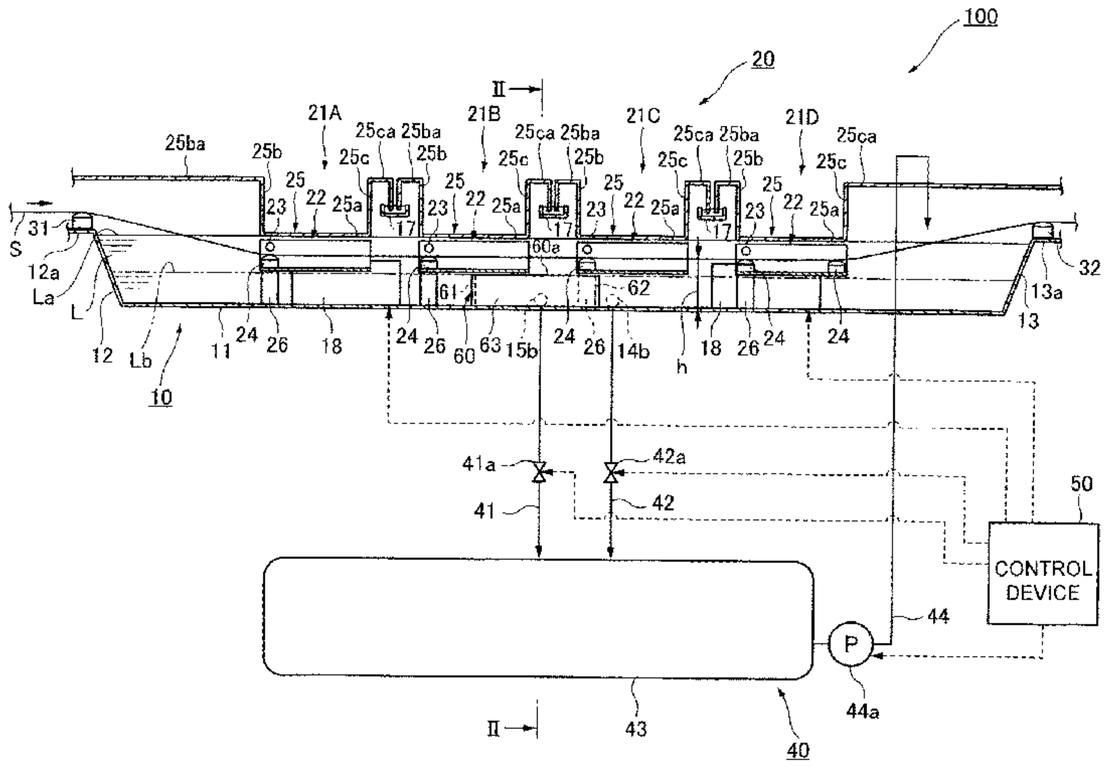
(57) **ABSTRACT**

To prevent over-pickling of a steel strip during pickling pause, and shorten the time required to switch between pickling operation and pickling pause, a pickling device includes: a pickling tank for storing acid solution and for pickling a steel strip by allowing the steel strip to travel therethrough while the steel strip is immersed in the acid solution; a heat exchanger for heating the acid solution in the pickling tank; a circulation tank for storing the acid solution, provided separately from the pickling tank; an acid-solution circulation unit configured to circulate the acid solution between the pickling tank and the acid-solution storage tank; and a control device configured to control the acid-solution circulation device to maintain a liquid level of the acid solution in the pickling tank at a level below a traveling height of the steel strip.

5 Claims, 5 Drawing Sheets



(58) **Field of Classification Search**
USPC 134/105
See application file for complete search history.

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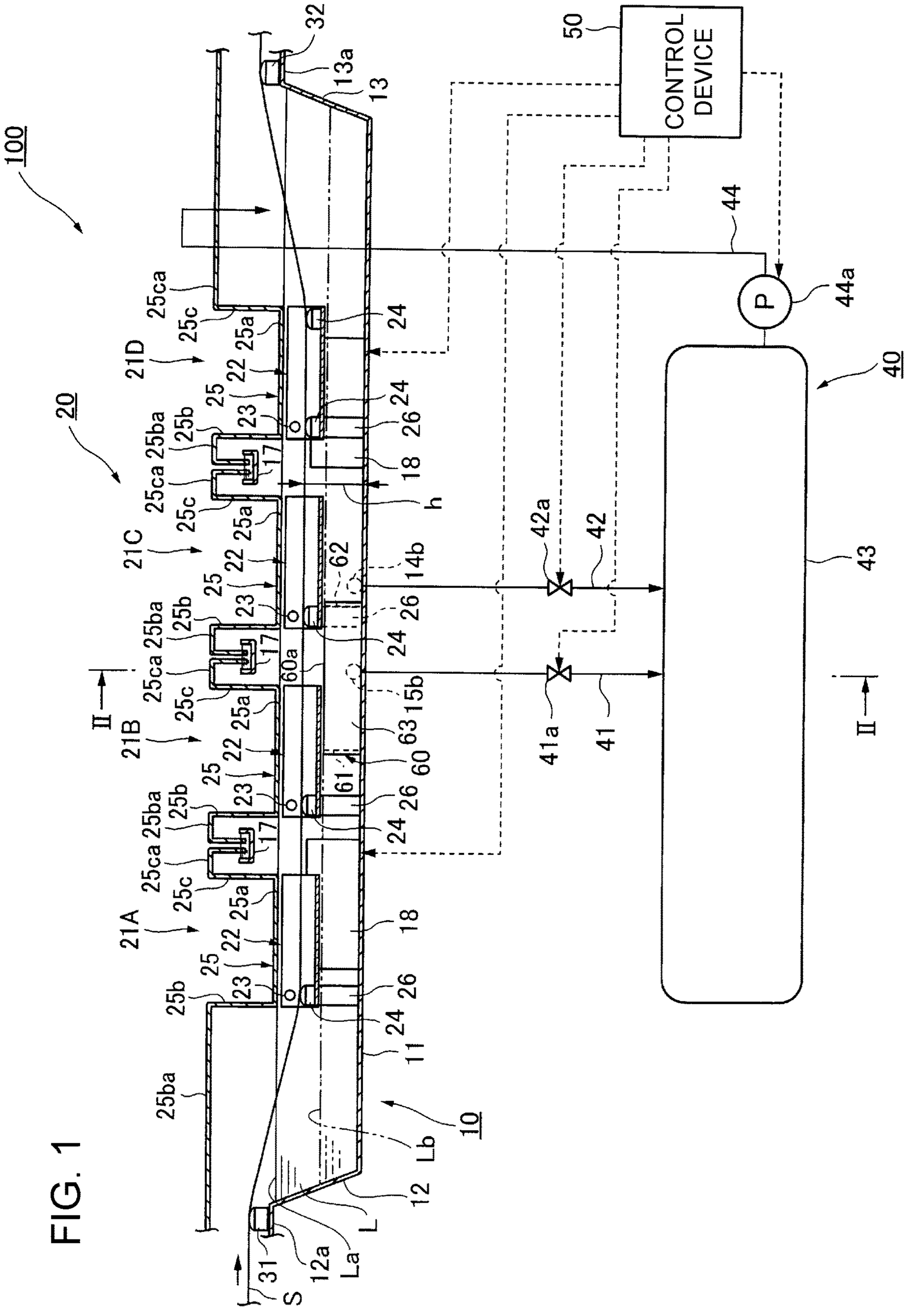
FIG. 1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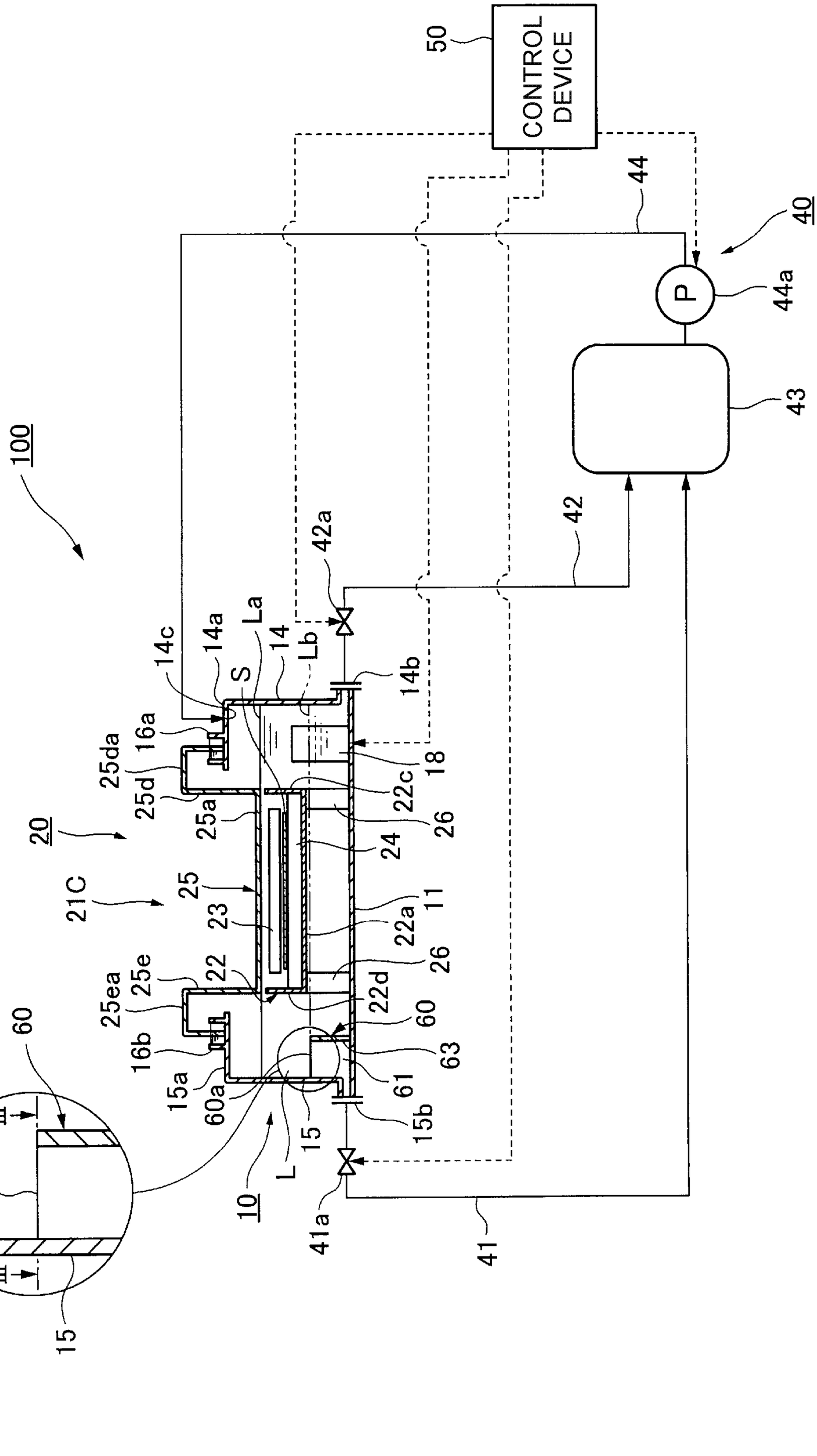
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22c
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22d
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16b
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FIG. 2

FIG. 3

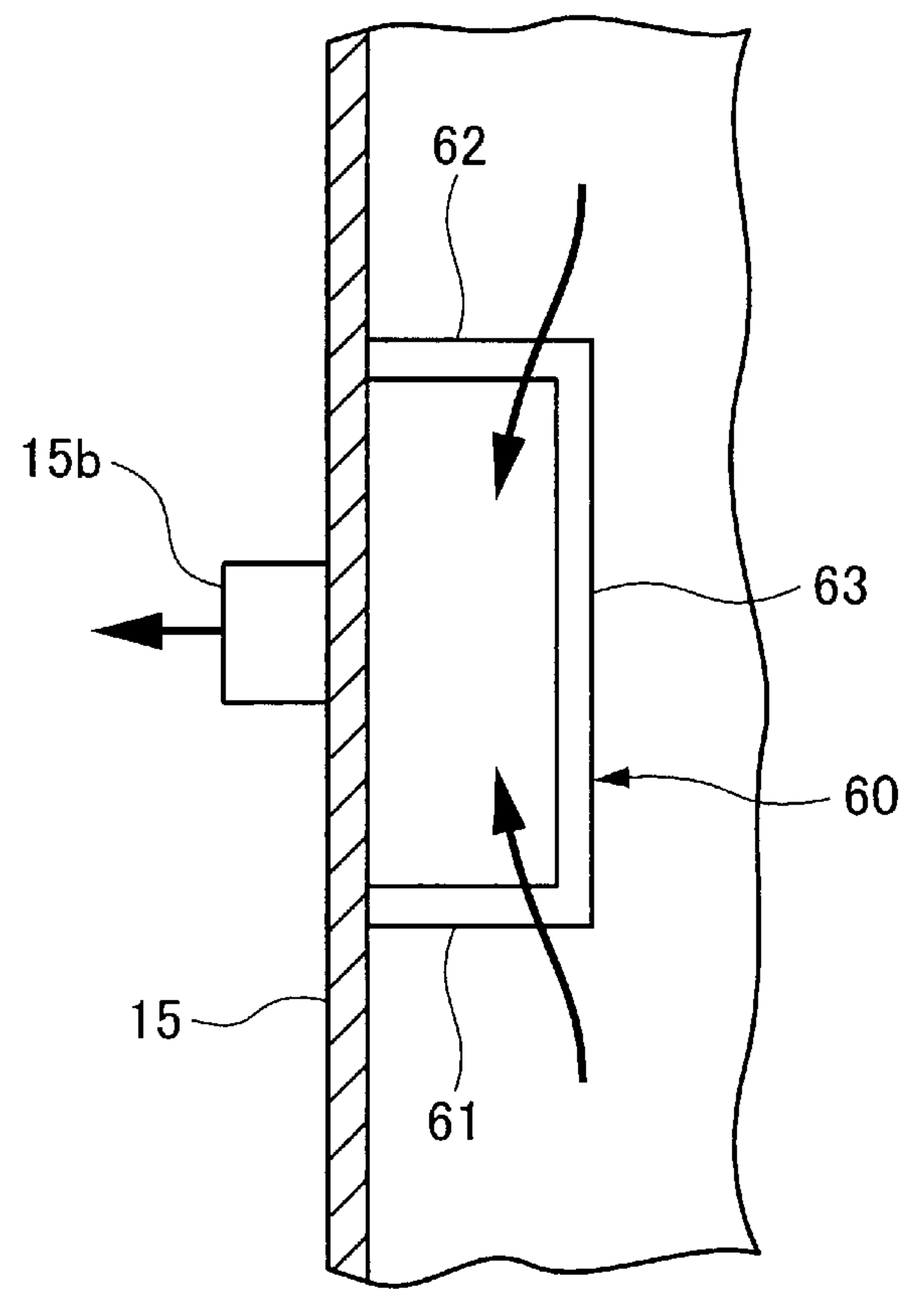
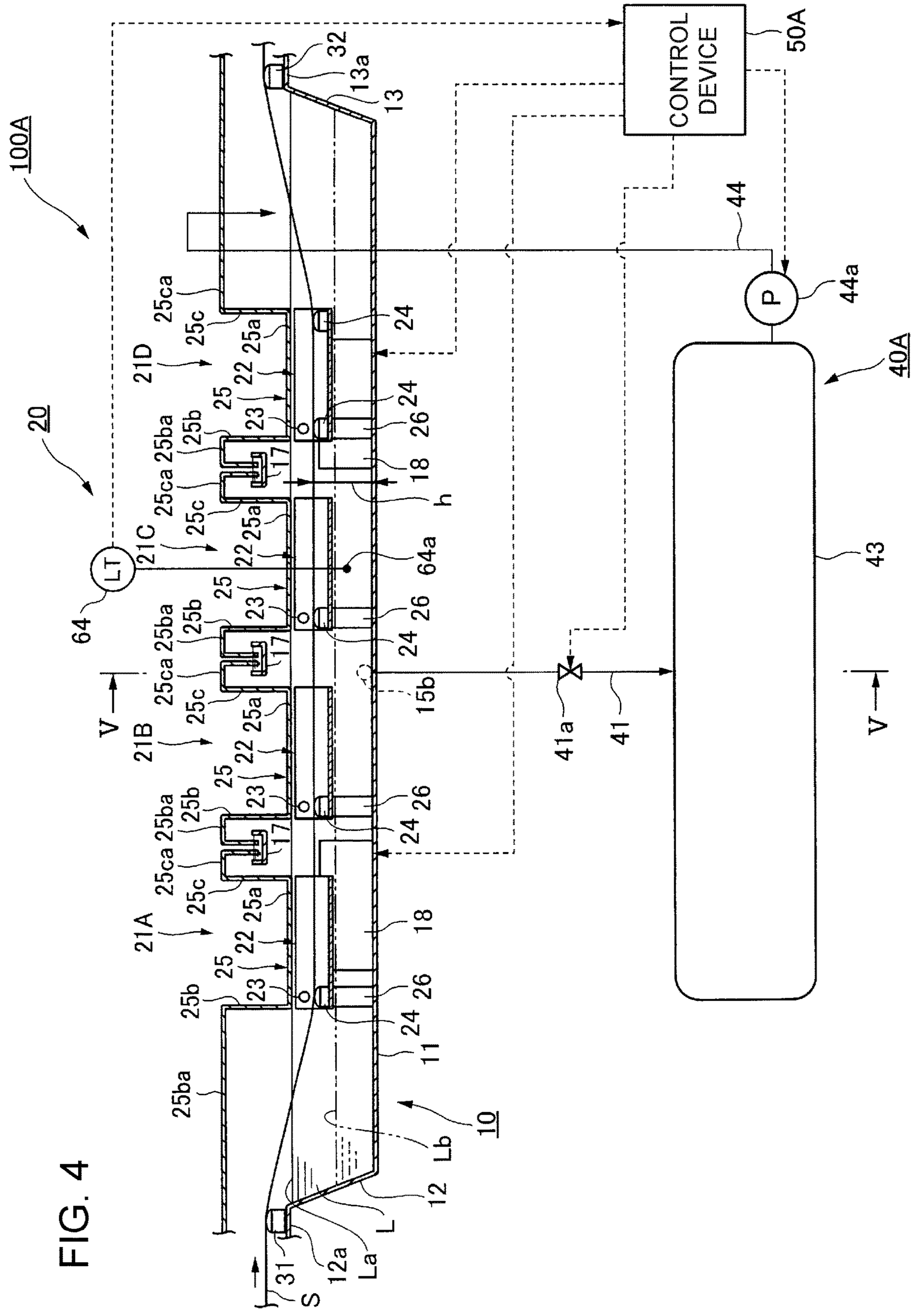


FIG. 4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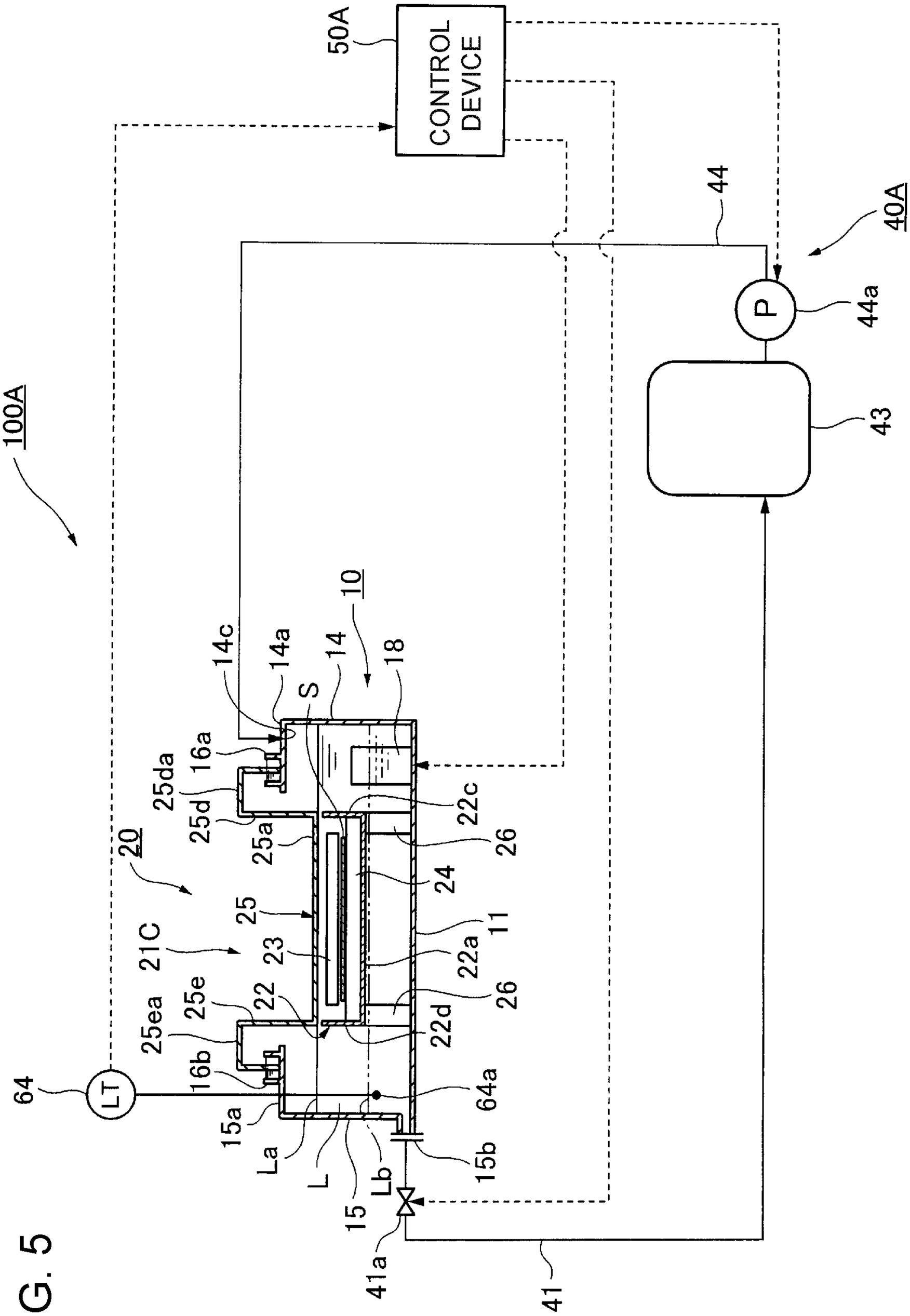
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21C
23
11
22a
25ea
25e
22
26
22d
16b
64
LT
64a
15a
La
L
15
Lb
15b
41a
41

FIG. 5

PICKLING DEVICE AND PICKLING PAUSE OPERATION METHOD

TECHNICAL FIELD

The present invention relates to a pickling device and a pickling pause operation method of the same.

BACKGROUND ART

A pickling device is a device for cleaning and removing oxidized scales, which are oxidized matter formed on a surface of a steel strip such as a cold-rolled steel plate and a hot-rolled steel plate, by causing the oxidized scales to react with acid solution such as hydrochloric acid and sulfuric acid. In a general pickling device, as a steel strip is fed continuously into a pickling tank, acid solution is sprayed onto the steel strip, or the steel strip is immersed in acid solution stored in the pickling tank, and thereby oxidized scales on the surface of the steel strip are removed continuously.

Patent Document 1 discloses a pickling device including: a pickling tank including an acid-solution receiving tank having a shape that is elongated in the traveling direction of a steel strip and is shallow in the middle with respect to the longitudinal direction and deep at both of the inlet and outlet end portions, and a tank lid covering the acid-solution receiving tank; skids disposed on the tank bottom at both sides of the middle part of the acid-solution receiving tank; a plurality of support rolls disposed between the skids; an acid-solution feeding header which injects acid solution onto the steel strip supported by the support rolls; a circulation tank connected to the acid-solution feeding header via an acid-solution feeding line and connected to the acid-solution receiving tank via a return line; and a heat exchanger disposed in the acid-solution feeding line, wherein the acid-solution feeding header injects acid solution to the steel strip to perform continuous pickling.

Patent Document 2 discloses a pickling device including: a pickling tank filled with acid solution; a lid covering an upper part of the pickling tank; an immersion guide roll disposed rotatably on the lower surface of the lid; a support block disposed on the bottom surface of the pickling tank; a bottom plate disposed on an upper part of the support block; and a skid disposed on the upper surface of the bottom plate to face the immersion guide roll, wherein the pickling device performs pickling of a steel strip by causing the steel strip to travel through the acid solution while guiding the steel strip with the immersion guide roll and the skid.

CITATION LIST

Patent Literature

Patent Document 1: JP2004-91856A
Patent Document 2: JP3160300B

SUMMARY

Problems to be Solved

Meanwhile, in a facility with a pickling device, travel of a steel strip may be stopped temporarily (e.g. from a couple of hours to one day), for maintenance or the like of a device disposed upstream or downstream of the pickling device with respect to the traveling direction of the steel strip. At this time, stopping travel of the steel strip while the steel strip is immersed in the acid solution of the pickling tank leads to further progression of pickling of the steel strip, which causes over-pickling. Thus, in a typical case, the acid solution in the pickling tank is transferred to a circulation tank provided separately from the pickling tank, or the steel strip is lifted above the acid solution.

The pickling device disclosed in Patent Document 1 is capable of transferring the acid solution in the pickling tank to the circulation tank during pickling pause to prevent over-pickling of a steel strip, and heating the acid solution with a heat exchanger during pickling operation. However, the temperature of the acid solution decreases with duration of pickling pause, and long time is required to switch from pickling pause to pickling operation.

The pickling device disclosed in Patent Document 2 needs to lift not only the steel strip but also the immersion guide roll, the skid, and the like by using a lifting device, in order to prevent over-pickling of the steel strip during pickling pause. Thus, the lifting device needs to be a large device with a high strength, which may increase the apparatus cost. One may consider transferring the acid solution inside the pickling tank to a circulation tank provided separately from the pickling tank. However, the volume of acid solution is high, and the temperature of the acid solution decreases with duration of pickling pause, which may require long time to switch from pickling pause to pickling operation.

In view of the above, the present invention was made to solve the above described problem. An object of the present invention is to provide a pickling device capable of preventing over-pickling of a steel strip during pickling pause and reducing the switching time between pickling operation and pickling pause, and a method of operating the pickling device during pickling pause.

Solution to the Problems

According to the present invention for solving the above problem, a pickling device includes: a pickling tank for storing acid solution and for pickling a steel strip by allowing the steel strip to travel therethrough while the steel strip is immersed in the acid solution; a heating unit for heating the acid solution in the pickling tank; an acid-solution storage tank for storing the acid solution, provided separately from the pickling tank; an acid-solution circulation unit configured to circulate the acid solution between the pickling tank and the acid-solution storage tank; and a liquid level adjustment unit configured to control the acid-solution circulation unit to maintain a liquid level of the acid solution in the pickling tank at a level below a traveling height of the steel strip.

According to the present invention for solving the above problem, a method of operating, during pickling pause, a pickling device which includes: a pickling tank for pickling a steel strip by allowing the steel strip to travel therethrough while the steel strip is immersed in acid solution; a heating unit for heating the acid solution in the pickling tank; and a circulation unit configured to circulate the acid solution between an acid-solution storage tank for storing the acid solution and the pickling tank, includes: during pickling pause of the steel strip, circulating the acid solution between the acid-solution storage tank and the pickling tank with the acid-solution circulation unit while maintaining a liquid level of the acid solution inside the pickling tank at a level below a traveling height of the steel strip, and heating the circulating acid solution with the heating unit inside the pickling tank.

Advantageous Effects

According to the present embodiment, during pickling pause of a steel strip, the acid solution circulates between the pickling tank and the acid-solution storage tank while the liquid level of the acid solution inside the pickling tank is maintained to be below the traveling height of the steel strip, and thereby it is possible to prevent over-pickling of the steel strip during pickling pause. Furthermore, the acid solution is heated by the heating unit to the predetermined temperature and is circulated between the pickling tank and the acid-solution storage tank with the acid-solution circulation unit. Thus, as compared to a case in which the entire acid solution is discharged from the pickling tank and stored in a tank separate from the pickling tank, it is possible shorten the time required to switch between pickling operation and pickling pause.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is schematic side view of a pickling device according to the first embodiment of the present invention.

FIG. **2** is a cross-sectional view taken along line II-II in FIG. **1**.

FIG. **3** is a cross-sectional view taken along line in FIG. **2**.

FIG. **4** is schematic side view of a pickling device according to the second embodiment of the present invention.

FIG. **5** is a cross-sectional view taken along line V-V in FIG. **4**.

DETAILED DESCRIPTION

Hereinafter, embodiments of a pickling device and a method of operating the pickling device during pickling pause according to the present invention will be described with reference to the drawings. Nevertheless, the present invention should not be limited only to the following embodiments.

First Embodiment

With reference to FIGS. **1**, **2**, and **3**, the pickling device according to the first embodiment of the present invention will now be described.

As shown in FIGS. **1** and **2**, a pickling device **100** according to the present embodiment includes a pickling tank **10**, a circulation tank (acid-solution storage tank) **43**, an acid-solution circulation device (acid-solution circulation unit) **40**, and a control device (liquid level adjustment unit) **50**.

The pickling tank **10** is a deep tank. The pickling tank **10** includes: a tank body having a bottom plate **11**, a front plate **12**, a rear plate **13**, a right plate **14**, and a left plate **15**, which is open at the top, and is capable of storing acid solution L; and a plurality of (four in the illustrated example) cover members **25** covering the opening of the tank body. The bottom plate **11** extends in the traveling direction (feeding direction) of a steel strip S, and is inclined such that the bottom plate **11** reaches its lowermost point at the first drain port **15***b* (central circulation port) described below in detail. The front plate **12**, the rear plate **13**, the right plate **14**, and the left plate **15** form vertical walls of the pickling tank **10**. It should be noted that the pickling tank **10** and the cover members **25** may be made of an acid-resistant material such as a resin like polypropylene and a composite containing the same, or of a steel can member with rubber lining, further covered with acid-resistant bricks.

The front plate **12** is connected to a front end portion of the bottom plate **11**, disposed on the upstream side with respect to the traveling direction of the steel strip S. The rear plate **13** is connected to a rear end portion of the bottom plate **11**, disposed on the downstream side with respect to the traveling direction of the steel strip S. The right plate **14** is connected to the right end portion of the bottom plate **11** with respect to the width direction, entirely in the traveling direction of the steel strip S. The upstream end portion and the downstream end portion of the right plate **14**, with respect to the traveling direction of the steel strip S, are connected to the front plate **12** and the rear plate **13**. The left plate **15** is connected to the left end portion of the bottom plate **11** with respect to the width direction, entirely in the traveling direction of the steel strip S. The upstream end portion and the downstream end portion of the left plate **15**, with respect to the traveling direction of the steel strip S, are connected to the front plate **12** and the rear plate **13**.

The left plate **15** and the right plate **14** have the first drain port **15***b* and the second drain port **14***b* formed thereon, respectively, in the middle and at the lower side with respect to the traveling direction of the steel strip S.

On the upper end portion side of the front plate **12**, a front flange portion **12***a* is formed so as to extend horizontally upstream in the traveling direction of the steel strip S. On the upper end portion side of the rear plate **13**, a rear flange portion **13***a* is formed so as to extend horizontally downstream in the traveling direction of the steel strip S. An inlet skid **31** is disposed on the front flange portion **12***a*, and an outlet skid **32** is disposed on the rear flange portion **13***a*.

On the upper end portion side of the right plate **14** and the left plate **15**, a right flange portion **14***a* and a left flange portion **15***a* are formed, respectively, so as to extend inward in the width direction of the pickling tank **10**. A right receiving portion **16***a* is disposed on the right flange portion **14***a*, and a left receiving portion **16***b* is disposed on the left flange portion **15***a*. The right receiving portion **16***a* and the left receiving portion **16***b* are both filled with seal solution, such that end portions of the right plates **25***d* and the left plates **25***e* of the cover members **25** are immersed in the seal solution. Accordingly, the upper sides of both end portions of the pickling tank **10**, with respect to the width direction, are sealed with the cover members **25**.

A plurality of (three in the illustrated example) width-directional receiving portions **17** are disposed to connect the right plate **14** and the left plate **15** so as to form a shape that extends in the width direction of the pickling tank **10**. The plurality of width-directional receiving portions **17** are arranged next to one another in the traveling direction of the steel strip S.

The plurality of width-directional receiving portions **17** are disposed between guide device bodies (described below) arranged next to one another in the traveling direction of the steel strip S. The width-directional receiving portions **17** are filled with seal solution, such that end portions of the front plates **25***b* and the rear plates **25***c* of the cover members **25** are immersed in the seal solution. Accordingly, the upper sides between the guide device bodies, arranged next to one another with respect to the traveling direction of the steel strip S in the pickling tank **10**, are sealed with the cover members **25**.

The pickling tank **10** includes a plurality (two in the illustrated example) heat exchangers (heating units). The plurality of heat exchangers **18** are arranged next to one another in the traveling direction of the steel strip S. The heat

exchangers **18** are disposed on the bottom plate **11** of the pickling tank **10**, under the right flange portion **14***a* and in the vicinity of the right plate **14**. The heat exchangers **18** are substantially flush with the traveling height h of the steel strip S. Furthermore, the heat exchangers **18** are each a heat-transfer tube which is arranged to extend in the height direction and the side-plate width direction, and which has a function of indirect heating through supply of a heat medium (e.g. steam) into the tube. Thus, with at least a part of the heat exchangers **18** being immersed in the acid solution L in the pickling tank **10**, it is possible to heat the acid solution L in the pickling tank **10** to a predetermined temperature.

The pickling tank **10** includes a guide device (steel strip guide device) **20** for guiding the steel strip S. The guide device **20** includes a plurality of (four in the illustrated example) guide device bodies **21**A to **21**D. The plurality of guide device bodies **21**A to **21**D are arranged next to one another in the traveling direction of the steel strip S. The guide device bodies **21**A to **21**D each includes a gutter-shaped member (immersion box) **22** having a U-shaped lateral cross section, an immersion guide roll **23**, a skid **24**, and a support block **26**.

The gutter-shaped member **22** has a shape that extends in the traveling direction of the steel strip S and has openings on the upstream side and the downstream side with respect to the traveling direction of the steel strip S. The gutter-shaped member **22** has a bottom plate portion **22***a*, a right plate portion **22***c*, and a left plate portion **22***d*. The right plate portion **22***c* and the left plate portion **22***d* are disposed so as to face each other. An end portion of the bottom plate portion **22***a* (an end portion with respect to the width direction of the steel strip S) and the other end portion of the bottom plate portion **22***a* (the other end portion with respect to the width direction of the steel strip S) are connected to the right plate portion **22***c* and the left plate portion **22***d* entirely in the traveling direction of the steel strip S. The gutter-shaped member **22** is supported by the support block **26**.

The skid **24** is disposed on the front end portion side of the bottom plate portion **22***a*, which forms an upstream end portion with respect to the traveling direction of the steel strip S. In the fourth guide device body **21**D disposed downstream with respect to the traveling direction of the steel strip S, the skid **24** is also disposed on the rear end portion side of the bottom plate portion **22***a*, which forms a downstream end portion with respect to the traveling direction of the steel strip S. An immersion guide roll **23** is disposed on the front end portion side of a cover member body **25***a* described below in detail, which forms an upstream end portion with respect to the traveling direction of the steel strip S.

The support block **26** is disposed below the skid **24**, on the front end portion side of the bottom plate portion **22***a*, which forms an upstream end portion with respect to the traveling direction of the steel strip S. The support block **26** is disposed on each of both end portions with respect to the width direction of the steel strip S. Accordingly, the guide device bodies **21**A to **21**D are arranged at a predetermined height inside the pickling tank **10**. Thus, during pickling operation for the steel strip S, the pickling tank **10** is filled with acid solution L to the substantially same height as the guide device bodies **21**A to **21**D, and the steel strip S is guided while being immersed in the acid solution L (at a predetermined traveling height h).

The cover member **25** includes a cover member body **25***a*, a front plate **25***b*, a rear plate **25***c*, a right plate **25***d*, and a left plate **25***e*. The cover member body **25***a* has a plate shape. The cover member body **25***a* is disposed above the gutter-shaped member **22**.

The front plate **25***b* has a shape that connects to the front end portion of the cover member body **25***a*, and extends upward. On the upper end portion side of the front plate **25***b*, a front flange portion **25***ba* is formed so as to extend upstream in the traveling direction of the steel strip S. With regard to the cover member **25** arranged corresponding to each of the second to fourth guide device bodies **21**B to **21**D, a tip end portion of the front flange portion **25***ba* of the front plate **25***b* is bended downward and immersed in seal solution stored in the width-directional receiving portion **17**.

The rear plate **25***c* has a shape that connects to the rear end portion of the cover member body **25***a*, and extends upward. On the upper end portion of the rear plate **25***c*, a rear flange portion **25***ca* is formed so as to extend downstream in the traveling direction of the steel strip S. With regard to the cover member **25** arranged corresponding to each of the first to third guide device bodies **21**A to **21**C, a tip end portion of the rear flange portion **25***ca* of the rear plate **25***c* is bended downward and immersed in the seal solution stored in the width-directional receiving portion **17**.

The right plate **25***d* has a shape that connects to the right end portion of the cover member body **25***a*, and extends upward. On the upper end portion side of the right plate **25***d*, a right flange portion **25***da* is formed so as to extend outward in the width direction of the steel strip S. A tip end portion of the right flange portion **25***da* is bended downward and immersed in the seal solution stored in the right receiving portion **16***a*.

The left plate **25***e* has a shape that connects to the left end portion of the cover member body **25***a*, and extends upward. On the upper end portion of the left plate **25***e*, a left flange portion **25***ea* is formed so as to extend outward in the width direction of the steel strip S. A tip end portion of the left flange portion **25***ea* is bended downward and immersed in the seal solution stored in the left receiving portion **16***b*.

Accordingly, the cover members **25** provided corresponding to the first to fourth guide device bodies **21**A to **21**D cover the pickling tank **10** from above.

The acid-solution circulation device **40** includes a first drain pipe (flow passage for acid solution) **41**, a second drain pipe **42**, and a supply pipe (return pipe) **44**. The first drain pipe **41** has a root end side (an end portion side) connected to the first drain port **15***b* of the pickling tank **10**, and a distal end side (the other portion side) connected to the circulation tank **43**. An opening-and-closing valve **41***a* is disposed in the first drain pipe **41**. The second drain pipe **42** has a root end side connected to the second drain port **14***b* of the pickling tank **10**, and a distal end side (the other end portion side) connected to the circulation tank **43**. An opening-and-closing valve **42***a* is disposed in the second drain pipe **42**. The supply pipe **44** has a root end side (an end portion side) connected to the circulation tank **43**, and a distal end side (the other end portion side) connected to the supply port **14***c* of the pickling tank **10**. A circulation pump **44***a* is disposed in the supply pipe **44**. Preferably, the circulation tank **43** is disposed below the pickling tank **10**. In this way, it is possible to drain the acid solution L from the pickling tank **10** into the circulation tank **43** without a pump.

As shown in FIGS. **1** to **3**, the pickling device **100** further includes a dam **60** disposed inside the pickling tank **10**. The drain port **15***b* is disposed on a lower end of the left plate **15**, in the middle with respect to the width direction. The dam **60** has a shape that surrounds the first drain port **15***b*, and includes a front plate portion **61**, a rear plate portion **62**, and

a side plate portion **63**. The front plate portion **61** of the dam **60** has a shape that connects to the left plate **15** and the bottom plate **11** and extends in the width direction of the pickling tank **10**. The rear plate portion **62** of the dam **60** is connected to the left plate **15** and the bottom plate **11**. The rear plate portion **62** of the dam **60** is disposed at a distance from the front plate portion **61**, and has a shape that extends parallel to the front plate portion **61**. The side plate portion **63** of the dam **60** has a shape that connects to an end portion of the front plate portion **61**, an end portion of the rear plate portion **62**, and the bottom plate **11**, and extends in the traveling direction of the steel strip S. The upper end portion (inlet) **60***a* of the dam **60** is preferably disposed in a range below the traveling height h of the steel strip S inside the pickling tank **10**, and above the ⅓ height of the liquid level La of the acid solution L during pickling operation. More preferably, the upper end portion **60***a* of the dam **60** is disposed in a range below the bottom plate portion **22***a* of the gutter-shaped member **22** and above the ½ height of the liquid level La of the acid solution L during pickling operation. In this way, during pickling pause, it is possible to heat the acid solution L with the heat exchangers **18** efficiently, while suppressing a discharge amount of the acid solution L from the pickling tank **10**. Furthermore, it is possible to switch between pickling operation and pickling pause in a small amount of time. In other words, the dam **60** forms an inflow passage connecting to the first drain port **15***b*, and forms a part of a liquid-level adjustment unit configured to adjust and maintain the liquid level Lb of the acid solution L to be below the traveling height h of the steel strip S by allowing the acid solution L to flow over the upper end portion **60***a*. It should be noted that the inflow passage may be disposed outside the pickling tank **10**, with the inlet connected to the left plate **15** of the pickling tank **10**.

Preferably, the dam **60** and the pickling tank **10** are made of the same material. If the pickling tank **10** is made of a resin, the dam **60** may be preferably made of the same resin as the pickling tank **10**. In this way, the dam **60** can expand thermally along with the pickling tank **10**, which holds the acid solution L having a high temperature (e.g. 85 to 90° C.) during pickling operation and pickling pause. If the pickling tank **10** and the dam **60** are made of different materials, there is an increased risk of breakage occurring due to difference in the thermal expansion at joints between the pickling tank **10** and the dam **60**.

The control device **50** is a device for controlling each component of the pickling device **100**. The output side of the control device **50** is connected to the heat exchangers **18**, the opening-and-closing valves **41***a*, **42***a*, and the circulation pump **44***a*, and is configured to be capable of controlling these components.

The main operation of the above described pickling device **100** will be described below.

During pickling operation, the control device **50** controls the heat exchangers **18** so as to heat the acid solution L to a predetermined temperature (e.g. 85 to 90° C.), and controls the acid-solution circulation device **40** such that the acid solution L does not circulate. In other words, the control device **50** controls the opening-and-closing valves **41***a*, **42***a* disposed in the first and second drain pipes **41**, **42** to be fully closed, and controls the circulation pump **44***a* to stop. Accordingly, inside the pickling tank **10**, the acid solution L is heated to the predetermined temperature, and the liquid level La of the acid solution L is maintained at the substantially same level as the cover member bodies **25***a* of the cover members **25**. Thus, the steel strip S undergoes the pickling process, by traveling through the acid solution L while being immersed in the acid solution L, guided by the immersion guide rolls **23** and the skids **24**.

During pickling pause, in which pickling operation is stopped temporarily (e.g. from a couple of hours to one day), the control device **50** controls the heat exchangers **18** so as to heat the acid solution L to a predetermined temperature (e.g. 85 to 90° C.), and controls the acid-solution circulation device **40** so as to circulate the acid solution L. In other words, the control device **50** controls the opening-and-closing valve **42***a* disposed in the second drain pipe **42** to be fully closed, and controls the opening-and-closing valve **41***a* disposed in the first drain pipe **41** to be fully open. Accordingly, the acid solution L inside the pickling tank **10** flows over the upper end portion **60***a* of the dam **60** and passes through the inside of the dam **60** downward to reach the vicinity of the first drain port **15***b*, and then flows from the first drain port **15***b* through the first drain pipe **41** into the circulation tank **43**, where the acid solution L is temporarily stored. The acid solution L inside the pickling tank **10** is discharged into the circulation tank **43** via the first drain pipe **41**, such that the liquid level Lb of the acid solution L inside the pickling tank **10** becomes substantially flush with the upper end portion **60***a* of the dam **60**. Then, the control device **50** controls the opening degree of the opening-and-closing valve **41***a*, and controls the circulation pump **44***a* to operate. Accordingly, the acid solution L stored temporarily inside the circulation tank **43** flows into the pickling tank **10** via the supply pipe **44** in response to operation of the circulation pump **44***a*. That is, the first drain pipe **41** and the supply pipe **44** form two flow passages through which the acid solution L flows between the pickling tank **10** and the circulation tank **43**. Whether the acid solution L is substantially flush with the upper end portion **60***a* of the dam **60** may be determined on the basis of a signal from a liquid level sensor provided in advance, or on the basis of elapse of time that the acid solution L takes to reach the upper end portion **60***a* of the dam **60**, the time being obtained in advance. Through design or adjustment to keep the flow volume (supply amount) of acid solution supplied to the pickling tank **10** with the circulation pump **44***a* below a flow volume (discharge amount) at which acid solution can flow out the pickling tank **10** over the dam **60**, the liquid level of the acid solution L can be maintained at the same level as the upper end portion **60***a* of the dam **60**.

Thus, during pickling pause, the liquid level Lb of the acid solution L inside the pickling tank **10** is lowered to the substantially same level as the upper end portion **60***a* of the dam **60**, which is below the traveling height h of the steel strip S inside the pickling tank **10**. In this state, the acid solution L is circulated by the acid-solution circulation device **40** between the pickling tank **10** and the circulation tank **43**, and the circulating acid solution L is heated to the predetermined temperature by the heat exchangers **18** inside the pickling tank **10**.

Thus, according to the present embodiment, during pickling pause, in which pickling of the steel strip S is temporarily stopped, the acid solution L circulates between the pickling tank **10** and the circulation tank **43** while the liquid level Lb of the acid solution L inside the pickling tank **10** is maintained to be below the traveling height h of the steel strip S, and thereby it is possible to prevent over-pickling of the steel strip S. Furthermore, the acid solution L is heated by the heat exchangers **18** to the predetermined temperature and is circulated by the acid-solution circulation device **40** between the pickling tank **10** and the circulation tank **43**. Thus, as compared to a case in which the total volume of acid solution is discharged from the pickling tank and stored

in a tank separate from the pickling tank, a smaller volume of the acid solution L is returned to the pickling tank **10**, which makes it possible to prevent a temperature decrease of the acid solution due to storage of the acid solution in a separate tank, and to shorten the time required to switch between pickling operation and pickling pause.

The control device **50** is configured to control opening and closing of the opening-and-closing valve **41***a* and operation of the circulation pump **44***a*. Therefore, even though the configuration is simple, it is possible to prevent over-pickling of the steel strip S during pickling pause reliably, and to shorten the time required to switch between pickling operation and pickling pause.

The height of the dam **60** is set so that the acid solution L has a liquid level such that the heat exchangers **18** are partially immersed in the acid solution L so as to enable heating that is necessary to maintain the acid solution temperature. Accordingly, it is possible to heat the acid solution L inside the pickling tank **10** reliably with the heat exchangers **18**.

The pickling tank **10** has a depth such that the upper edge of each heat exchanger **18** is arranged in the acid solution L at the substantially same level as the traveling height h of the steel strip S, and the pickling tank **10** is provided with the guide device **20** for guiding the steel strip S to travel at a predetermined height in the acid solution L when the steel strip S is pickled with the acid solution L in the pickling tank **10**. Accordingly, it is possible to prevent over-pickling of the steel strip during pickling pause reliably and shorten the time required to switch between pickling operation and pickling pause, even though the configuration is simple, as compared to a case in which, during pickling pause, the guide device and the steel strip are lifted above the liquid level of the acid solution with a lifting device or the total volume of the acid solution in the pickling tank is transported to a separate tank.

Second Embodiment

With reference to FIGS. **4** and **5**, the pickling device according to the second embodiment of the present invention will now be described.

The present embodiment has a configuration in which the acid-solution circulation device and the control device provided for the above described first embodiment shown in FIGS. **1** and **2** are modified. The other configuration is similar to that of the above described device shown in FIGS. **1** and **2**, and the same feature is indicated by the same reference numeral and not described again in detail.

As shown in FIGS. **4** and **5**, a pickling device **100**A according to the present embodiment includes the same devices as the pickling device **100** according to the above described first embodiment, as well as an acid-solution circulation device (acid-solution circulation unit) **40**A, a liquid level sensor (liquid-level measurement unit) **64**, and a control device (liquid-level adjustment unit) **50**A. That is, the pickling device **100**A includes a liquid level sensor **64** in place of the dam provided for the pickling device **100**.

The acid-solution circulation device **40**A includes a first drain pipe **41**, an opening-and-closing valve **41***a*, a supply pipe **44**, and a circulation pump **44***a*. In the present embodiment, the opening degree of the opening-and-closing valve **41***a* is controlled, and the timing for driving the circulation pump **44***a* is also controlled. Accordingly, the acid solution L inside the pickling tank **10** is fed into the pickling tank **10** via the first drain pipe **41**, the circulation tank **43**, and the supply pipe **44**, and inside the pickling tank **10**, the liquid level Lb of the acid solution L is maintained at a predetermined level, below the traveling height h of the steel strip S.

The liquid level sensor **64** is a device for detecting the liquid level of the acid solution L inside the pickling tank **10**. The tip end portion **64***a* of the liquid level sensor **64** is positioned below the gutter-shaped member **22** of the guide device **20**. The output side of the liquid level sensor **64** is connected to the control device **50**A, and the liquid level sensor **64** detects the liquid level of the acid solution L inside the pickling tank **10** and sends information related to the liquid level of the acid solution L to the control device **50**A.

The input side of the control device **50**A is connected to the liquid level sensor **64**. The output side of the control device **50**A is connected to the heat exchangers **18**, the opening-and-closing valve **41***a*, and the circulation pump **44***a*.

The main operation of the above described pickling device **100**A will be described below.

During pickling operation, similarly to the control device **50** of the above described pickling device **100**, the control device **50**A controls the heat exchangers **18** so as to heat the acid solution L to a predetermined temperature (e.g. 85 to 90° C.), and controls the acid-solution circulation device **40**A so as not to circulate the acid solution L. In other words, the control device **50**A controls the opening-and-closing valve **41***a* disposed in the first drain pipe **41** to be fully closed, and controls the circulation pump **44***a* to stop. Accordingly, inside the pickling tank **10**, the acid solution L is heated to the predetermined temperature, and the liquid level La of the acid solution L is maintained at the substantially same level as the cover member bodies **25***a* of the cover members **25**. Thus, the steel strip S undergoes the pickling process, by traveling through the acid solution L while being immersed in the acid solution L, guided by the immersion guide rolls **23** and the skids **24**.

During pickling pause, in which pickling operation is stopped temporarily (e.g. from a couple of hours to one day), the control device **50**A controls the heat exchangers **18** so as to heat the acid solution L to a predetermined temperature (e.g. 85 to 90° C.), and controls the acid-solution circulation device **40**A so as to circulate the acid solution L. In other words, the control device **50**A controls the opening-and-closing valve **41***a* disposed in the first drain pipe **41** to be fully open. Accordingly, the acid solution L inside the pickling tank **10** flows from the first drain port **15***b* through the first drain pipe **41** into the circulation tank **43**, in which the acid solution L is temporarily stored. Then, when the liquid level Lb of the acid solution L inside the pickling tank **10** detected by the liquid level sensor **64** is below the guide device bodies **21**A to **21**D, the control device **50**A controls the opening degree of the opening-and-closing valve **41***a*, and controls the circulation pump **44***a* to operate. Accordingly, the acid solution L stored temporarily inside the circulation tank **43** flows into the pickling tank **10** via the supply pipe **44** in response to operation of the circulation pump **44***a*.

Accordingly, during pickling pause, the liquid level Lb of the acid solution L inside the pickling tank **10** is lowered to a level below the traveling height h of the steel strip S inside the pickling tank **10**, and in this state, the acid solution L is circulated by the acid-solution circulation device **40**A between the pickling tank **10** and the circulation tank **43**, and the circulating acid solution L is heated to the predetermined temperature by the heat exchangers **18** inside the pickling tank **10**.

Thus, according to the present embodiment, similarly to the above described first embodiment, during pickling

pause, in which pickling of the steel strip S is temporarily stopped, the acid solution L circulates between the pickling tank **10** and the circulation tank **43** while the liquid level Lb of the acid solution L inside the pickling tank **10** is maintained to be below the traveling height h of the steel strip S, and thereby it is possible to prevent over-pickling of the steel strip S during pickling pause. Furthermore, the acid solution L is heated by the heat exchangers **18** to the predetermined temperature and is circulated between the pickling tank **10** and the circulation tank **43** by the acid-solution circulation device **40**A. Thus, as compared to a case in which the total volume of acid solution is discharged from the pickling tank and stored in a tank separate from the pickling tank, a smaller volume of the acid solution L is returned to the pickling tank **10**, which makes it possible to prevent a temperature decrease of the acid solution due to storage of the acid solution in a separate tank, and to shorten the time required to switch between pickling operation and pickling pause.

The control device **50**A is configured to control opening and closing of the opening-and-closing valve **41***a* and operation of the circulation pump **44***a*. Therefore, even though the configuration is simple, the control device **50** can prevent over-pickling of the steel strip S during pickling pause reliably, and to shorten the time required to switch between pickling operation and pickling pause.

The control device **50**A is configured to control opening and closing of the opening-and-closing valve **41***a* and operation of the circulation pump **44***a* on the basis of the liquid level of the acid solution L measured by the liquid level sensor **64**. Therefore, even though the configuration is simple, the control device **50** can prevent over-pickling of the steel strip S during pickling pause more reliably, and to shorten the time required to switch between pickling operation and pickling pause.

Other Embodiments

While the above described pickling device **100** includes the dam **60** surrounding the first drain port **15***b* as an inflow passage of the liquid level adjustment unit, the pickling device may include an overflow pipe disposed in the pickling tank as an inflow passage of the liquid level adjustment unit, which connects to the first drain port of the pickling tank and has an inlet positioned below the traveling height of the steel strip. Also in such a pickling device, the acid solution overflows through the overflow pipe, and thereby it is possible to maintain the liquid level of the acid solution below the traveling height of the steel strip.

While the above described pickling device **100**, **100**A includes the guide device **20** having a plurality of guide device bodies with the gutter-shaped member **22** including the immersion guide roll **23** and the skid **24**, arranged in the traveling direction of the steel strip S, the present invention may be applied to a pickling device provided with a support roll supporting the lower side of the steel strip so as to enable feeding of the steel strip.

While the above described pickling device **100**, **100**A includes the guide device **20** including four guide device bodies **21**A to **21**D, the number of guide device bodies is not limited to four, and may be three or less, or five or more, as long as the steel strip can be supported so as to be movable in the traveling direction of the steel strip while being immersed in the acid solution.

While the first drain port **15***b* and the second drain port **14***b* of the pickling tank **10** are connected to the first drain pipe **41** and the second drain pipe **42** and the supply port **14***c* of the pickling tank **10** is connected to the supply pipe **44** in the above described pickling tank **100**, and the first drain port **15***b* of the pickling tank **10** is connected to the first drain pipe **41** and the supply port **14***c* of the pickling tank **10** is connected to the supply pipe **44** in the pickling device **100**A, a flexible tube may be interposed between joints of the pickling tank and the drain pipe and the supply pipe. Accordingly, even if the pickling tank **10** thermally expands, the flexible tube can absorb thermal expansion of the pickling tank **10**.

While the above described pickling device **100**, **100**A includes two heat exchangers **18** arranged next to one another in the traveling direction of the steel strip S in the vicinity of the right plate **14** of the pickling tank **10**, the number of heat exchangers is not limited to two, and may be one, or three or more. The pickling device may include heat exchangers arranged only in the vicinity of the left plate **15** of the pickling tank **10**, or on both sides in the vicinity of the right plate **14** and in the vicinity of the left plate **15** of the pickling tank **10**.

While the above described pickling device **100**, **100**A includes the cover members **25** provided corresponding to the respective guide device bodies **21**A to **21**D, the pickling device may include a single cover member that covers the pickling tank **10** from above.

While the above described pickling device **100**, **10**A uses water seals to seal the end portions of the cover members **25**, the pickling device may use rubber packing where rubber seals are attached to end portions of the cover members.

While the above described pickling device **100**, **100**A includes the heat exchangers **18**, the pickling device may include a device capable of heating the acid solution L to a predetermined temperature, such as a heater, in place of the heat exchangers.

While the above described pickling device includes a pickling tank and a circulation tank disposed below the pickling tank, the arrangement of a pickling tank and a circulation tank is not limited to this. It is sufficient if the acid solution can be circulated between the pickling tank and the circulation tank by the acid-solution circulation device. A circulation tank may be disposed above a pickling tank, or a pickling tank and a circulation tank may be disposed at the same level. Furthermore, while the above described acid-solution circulation device **40**, **40**A includes the opening-and-closing valve **41***a* disposed in the first drain pipe **41**, and the circulation pump **44***a* disposed in the supply pipe **44**, it is sufficient if the acid solution can be circulated between the pickling tank and the acid-solution circulation tank. The acid-solution circulation device may include pumps disposed in both of the drain pipe and the supply pipe, or may include pumps and opening-and-closing valves disposed in both of the drain pipe and the supply pipe, or may include a pump disposed in the drain pipe and an opening-and-closing valve disposed in the supply pipe.

INDUSTRIAL APPLICABILITY

According to the present invention, it is possible to prevent over-pickling of a steel strip during pickling pause and reduce the switching time between pickling operation and pickling pause. Thus, the present invention can be beneficially utilized in the metal manufacturing industry, for instance.

DESCRIPTION OF REFERENCE NUMERALS

1 Pickling tank
11 Bottom plate

14 Right plate
14*b* Second drain port
14*c* Supply port
15 Left plate
15*b* First drain port
16*a* Right receiving portion
16*b* Left receiving portion
17 Width-directional receiving portion
18 Heat exchanger
20 Guide device
21A to **21**D Guide device body
22 Gutter-shaped member
23 Immersion guide roll
24 Skid
25 Cover member
26 Support block
31, **32** Inlet skid
40, **40**A Acid-solution circulation device
41 First drain pipe
41*a* Opening-and-closing valve
42 Second drain pipe
42*a* Opening-and-closing valve
43 Circulation tank (Acid-solution storage tank)
44 Supply pipe
44*a* Circulation pump
50, **50**A Control device (Liquid-level adjustment unit)
60 Dam
60*a* Upper end portion
64 Liquid level sensor (liquid-level measurement unit)
64*a* Tip end portion
100, **100**A Pickling device
h Traveling height of steel strip
L Acid solution
La Liquid level (during pickling operation)
Lb Liquid level (during pickling pause)
S Steel strip

The invention claimed is:

1. A pickling device, comprising:
a pickling tank for storing acid solution and for pickling a steel strip by allowing the steel strip to travel therethrough while the steel strip is immersed in the acid solution;
a heating unit for heating the acid solution in the pickling tank;
an acid-solution storage tank for storing the acid solution, provided separately from the pickling tank;
an acid-solution circulation unit configured to circulate the acid solution between the pickling tank and the acid-solution storage tank; and
a liquid level adjustment unit configured to control the acid-solution circulation unit to maintain a liquid level of the acid solution in the pickling tank at a level below a traveling height of the steel strip,
wherein the liquid-level adjustment unit includes an inflow passage which connects to a drain port for the acid solution disposed on the pickling tank,
wherein the inflow passage has an inlet positioned below the traveling height of the steel strip and above the drain port, and
wherein the liquid-level adjustment unit is configured to allow the acid solution in the pickling tank to overflow from the inlet to maintain the liquid level of the acid solution in the pickling tank at the level of the inlet,
wherein the inflow passage is a dam which surrounds the drain port for the acid solution.

2. The pickling device according to claim **1**,
wherein the acid-solution circulation unit includes a flow passage between a drain port of the pickling tank and the acid-solution storage tank, a flow passage between a supply port of the pickling tank and the acid-solution storage tank, an opening-and-closing valve disposed in at least one of the two flow passages, and a pump disposed in at least the other one of the two flow passages, and
wherein the liquid-level adjustment unit is configured to control opening and closing of the opening-and-closing valve and operation of the pump.

3. The pickling device according to claim **1**,
wherein the heating unit is a heat exchanger, and
wherein the liquid-level adjustment unit is configured to adjust a liquid level of the acid solution so that at least a part of the heat exchanger is immersed in the acid solution.

4. A pickling device, comprising:
a pickling tank for storing acid solution and for pickling a steel strip by allowing the steel strip to travel therethrough while the steel strip is immersed in the acid solution;
a heating unit for heating the acid solution in the pickling tank;
an acid-solution storage tank for storing the acid solution, provided separately from the pickling tank;
an acid-solution circulation unit configured to circulate the acid solution between the pickling tank and the acid-solution storage tank; and
a liquid level adjustment unit configured to control the acid-solution circulation unit to maintain a liquid level of the acid solution in the pickling tank at a level below a traveling height of the steel strip,
wherein the acid-solution circulation unit includes a flow passage between a drain port of the pickling tank and the acid-solution storage tank, a flow passage between a supply port of the pickling tank and the acid-solution storage tank, an opening-and-closing valve disposed in at least one of the two flow passages, and a pump disposed in at least the other one of the two flow passages,
wherein the liquid-level adjustment unit is configured to control opening and closing of the opening-and-closing valve and operation of the pump, and
wherein the liquid-level adjustment unit includes a liquid-level measurement unit for measuring a liquid level of the acid solution, and is configured to control opening and closing of the opening-and-closing valve and operation of the pump on the basis of the liquid level of the acid solution measured by the liquid-level measurement unit.

5. A method of operating, during pickling pause, a pickling device which comprises: a pickling tank for pickling a steel strip by allowing the steel strip to travel therethrough while the steel strip is immersed in acid solution; a heating unit for heating the acid solution in the pickling tank; a circulation unit configured to circulate the acid solution between an acid-solution storage tank for storing the acid solution and the pickling tank; and a liquid level adjustment unit configured to control the acid-solution circulation unit to adjust a liquid level of the acid solution in the pickling tank, the liquid-level adjustment unit including an inflow passage which connects to a drain port for the acid solution disposed on the pickling tank, the inflow passage being a dam which surrounds the drain port for the acid solution and having an inlet positioned below a traveling height of the steel strip and above the drain port, the method comprising:

during pickling pause of the steel strip, circulating the acid solution between the acid-solution storage tank and the pickling tank with the circulation unit while maintaining a liquid level of the acid solution inside the pickling tank at a level of the inlet by allowing the acid solution in the pickling tank to overflow from the inlet by means of the liquid level adjustment unit, and heating the circulating acid solution with the heating unit inside the pickling tank.

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